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OFFICE NOTE 367

EVALUATING NUMERICAL MODEL QUANTITATIVE PRECIPITATION FORECASTS

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

INTRODUCTION

Objective evaluation of quantitative precipitation forecasts (QPF) is usually done by calculating precipitation threat scores and forecast biases for various quantitative precipitation (QP) categories. The selection of critical threshold amounts defining these categories is dependent on the length of the forecast interval with the convention of using one-quarter, one-half, or whole inch increments adopted for convenience.

Subjective interpretation of the quality of numerical model QPF is strongly influenced by the graphical representation of QP on rainfall charts; and the convention used is one-half inch contouring intervals.

Objective and subjective evaluation of model QPF is discussed in the following sections. A new verification score is derived and an example of its application is presented.

PRECIPITATION THREAT SCORE

The precipitation threat score (TSP) and bias (B) are defined by the formulas,

$$TSP = H \;/\; (F + O - H) \tag{1}$$

and

$$B = F \;/\; O \tag{2}$$

where, F = number of forecast precipitation events
O = number of observed precipitation events
H = number of hits or correct forecasts

A network of stations or gridpoints can be used to represent forecast and observed regions; also, actual measured forecast and observed areas may be used. Rewrite EQ (1),

$$TSP = H \;/\; \left[(F-H) + (O-H) + H\right] \tag{3}$$

where, (F-H) = number of incorrect forecast precipitation events
(O-H) = number of observed precipitation events that were not forecast

Figure Ia is a schematic representation of forecast (heavy line) and observed (thin line) precipitation areas. It is clear that TSP is that portion of the region defined by the forecast and observed precipitation events that was correctly forecast.

If F is greater than O everywhere and all of the observed precipitation events are correctly predicted, then,

$$H = O$$

and EQ (1) becomes,

$$TSP = H / F = O / F = 1 / B$$

The threat score is identical with the post-agreement (PA=H/F). In this case, TSP is the inverse of the bias.

If O is greater than F everywhere and all of the forecast precipitation events are correct, then,

$$H = F$$

and EQ (1) becomes,

$$TSP = H / O = F / O = B$$

The threat score is identical with the pre-figurance (PF=H/O). In this case, TSP is identical to the bias.

Maximum possible TSP for overforecasts varies inversely with B whereas for underforecasts it varies directly with B. In Figure II, variation of maximum TSP with bias is given by the solid line. Maxima decrease more slowly with excessive overforecasting than with excessive underforecasting; maxima are similar in the bias range between .8 and 1.2. In the absence of rainfall, zero is a a perfect score.

It is insufficient to use TSP by itself to characterize the quality of numerical model precipitation forecasts. The magnitude of the score depends on forecast bias and the occurrence, i.e, the opportunity to predict precipitation.

QUANTITATIVE PRECIPITATION THREAT SCORE

Figure Ib is identical to Figure Ia except that additional contouring is used to depict heavy QP amounts (dashed lines). A TSP can be calculated for these QP categories using appropriate F and O areas. In Figures Ic and Id, the areas specified by EQ (3) are shown for each of the two additional QP categories in Figure Ib.

Let x, y, and z define light, moderate, and heavy threshold amounts for three QP categories respectively. For z, the heaviest, from EQ (1),

$$TSPz = Hz / (Fz + Oz - Hz)$$

where, Fz, Oz, and Hz are F, O, and H that exceed the threshold amount for category z.

For category y, moderate amounts, EQ (1) becomes,

$$TSPy = Hy / (Fy + Oy - Hy)$$

where, $Fy = Fz + Fyz$
$Oy = Oz + Oyz$

$Hy = Hz + Hyz$

Fyz, Oyz, and Hyz are F, O, and H that exceed threshold y but are less than threshold z.

For category x, the lightest, EQ (1) becomes,

$$TSPx = Hx / (Fx + Ox - Hx)$$

where,
$$\begin{aligned} Fx &= Fy + Fxy = Fz + Fyz + Fxy \\ Ox &= Oy + Oxy = Oz + Oyz + Oxy \\ Hx &= Hy + Hxy = Hy + Hyz + Hxy \end{aligned}$$

Fxy, Oxy, and Hxy are F, O, and H that exceed threshold x but are less than threshold y.

The TSP calculated for a particular threshold amount, except for the heaviest QP category, includes all forecast, observed, and hits from QP categories exceeding the selected threshold. This is illustrated in Figure IIIa, which is a cross-section taken across the F and O areas of Figure Ib. Horizontal short-dashed lines are used for thresholds x, y, and z; for each QP category, the lateral dimension of the cross-sectional area (A=F+O-H) and the correctly forecast portion (H) are also indicated.

A set of threat scores and biases calculated for several precipitation threshold values, as discussed above, is the conventional method used in QPF evaluation. The overall assessment of QPF quality requires a subjective interpretation of the entire set of values or concentration on a specific category or two. At times this can be a difficult task since the sparsity of heavy precipitation events often yield wildly varying verification scores.

AN EXAMPLE

Consider the examples presented in Figure IV. In example 1 (top), the observed (OBSVD) contoured area represents greater than (GT) .50" amounts within a larger measureable precipitation area; maximum OBSVD is .58"; all amounts are less than one inch.

Two numerical model forecasts, FCST A and FCST B, are centered on the OBSVD; FCST A has a large GT .50" area with a maximum amount of .86" whereas FCST B has no value exceeding .46". FCST A is superior to FCST B in the prediction of the GT .50" area; FCST A has a TSP of .71 (bias is constructed to be 1.4) and FCST B has a score of zero.

In example 2 (middle, Figure IV), OBSVD, FCST A, and FCST B of example 1 are presented with a .40" isohyet; heavier amounts of FCST B are now enclosed by a contour; forecast biases are 1.4 and .7 for FCST A and FCST B respectively. Since both forecasts are centered over the OBSVD, FCST A correctly predicts all of the OBSVD while all of FCST B's GT .40" forecast is correct. TSP for the GT .40" category is .71 for FCST A and .70 for FCST B; the difference is nil.

Subjective preference in example 2 reduces to a choice between an overforecast or an underforecast. In general, meteorologists favor overforecasts, within reasonable limits, rather than underforecasts of heavy precipitation events. Therefore, there will still be disagreement between subjective and objective evaluation of forecasts presented in example 2; it is likely, however, that subjective impression of quality difference between model QPF is not the same as it was when presented in example 1 using the .50" contour. Note that .40" is approximately one centimeter.

The previous discussion is not meant to suggest that one-half and whole inch values chosen for contouring purposes and for defining critical QP thresholds are not useful. It is simply a reminder that evaluation and interpretation should not be confused with the tools and devices used to assist in such evaluation and interpretation.

In order to improve numerical model QPF it is imperative that the assessment of forecast quality be done with better measures of evaluation than simply the ability to exceed specified threshold amounts. In the following section, a QPF TSP is derived that is useful for this purpose.

ALTERNATIVE QUANTITATIVE PRECIPITATION THREAT SCORE

Instead of QP categories, consider the total range of forecast and observed rainfall amounts collectively. Correctly predicted amounts (QPH) depend on QPF and quantitative precipitation observed (QPO). If QPF and QPO are identical, QPH is equivalent to either one; whenever QPF and QPO differ, QPH is equal to the lesser of the two amounts. That is,

$$\text{QPH} = \begin{cases} \text{QPF} & \text{if QPO exceeds QPF} \\ \text{QPO} & \text{if QPF exceeds QPO} \\ \text{QPF or QPO} & \text{if QPF equals QPO} \end{cases} \qquad (4)$$

The various components of QPH as defined in EQ (4) are indicated along the bottom of the graph in Figure IIIb; this figure is identical with the cross-section given in Figure IIIa.

Using EQ (3),

$$\text{TSQP} = \text{QPH} \;/\; \left(\sum^{\text{QPF-QPH}} \text{QPF} + \sum^{\text{QPO-QPH}} \text{QPO} + \text{QPH} \right) \qquad (5)$$

where, $\text{QPH} = \sum^{a} \text{QPO} + \sum^{b} \text{QPF} + \sum^{c} \text{QPF (or QPO)}$

Area a. QPF exceeds QPO
Area b. QPO exceeds QPF
Area c. QPF equals QPO

The TSQP is the fraction of QPF correctly predicted with respect to the total volume of precipitation represented by the forecast and observed fields (see Figure IIIb).

If QPF is GT QPO everywhere and all of the observed is correctly predicted, that is,

$$QPH = QPO$$

then EQ (5) reduces to,

$$TSQP = \sum^{QPH} QPO \; / \; \left(\sum^{QPF-QPH} QPF + \sum^{QPH} QPF \right)$$

$$= \text{hits (i.e., observed)} \; / \; \text{forecast}$$

The threat score is identical with the post-agreement (PAQP=QPH/QPF). In this case, TSQP is the inverse of the QP bias (BQP=QPF/QPO). That is,

$$TSQP = 1 \; / \; BQP$$

If QPO is GT QPF everywhere and all of the forecast is correct, that is,

$$QPH = QPF$$

Then EQ (5) reduces to,

$$TSQP = \sum^{QPH} QPF \; / \; \left(\sum^{QPO-QPH} QPO + \sum^{QPH} QPO \right)$$

$$= \text{hits (i.e., forecast)} \; / \; \text{observed}$$

The threat score is identical with the pre-figurance (PFQP=QPH/QPO). In this case, TSQP is equal to the QP bias. That is,

$$TSQP = BQP$$

The maximum possible TSQP for overforecasts and underforecasts is also given by Figure II. For QP categorical forecsts, TSP is either zero or one, perfection or failure; all levels of overforecasting are treated alike; these limits are indicated by the dashed line in Figure II. In the absence of observed events in a category, a TSP of zero is perfect.

Now, reconsider the forecast example presented in Figure IV. At the bottom of Figure IV, cross-sections taken across FCST A and FCST B are presented on the left and right respectively; the .40" and .50" thresholds are drawn as dashed lines. In this illustration FCST A amounts are constructed to be on average 50% greater and FCST B 20% less than OBSVD average amounts. FCST A correctly predicts all of the OBSVD (QPH=QPO) whereas all of FCST B is correct (QPH=QPF of FCST B), biases are 1.5 and .8 respectively; TSQP for FCST A is .67 and for FCST B .80. By this method, FCST B's QPF is superior to FCST A.

This simple case has generated a wide range of assessments, both subjective and objective, on quality difference between model QPFs. Since the goal of numerical model guidance clients differ, it is likely that these contrary, but valid impressions exist; they reflect differing philosophical and methodologial viewpoints adopted in verification programs.

DISCUSSION

Evaluation of numerical model precipitation forecasts appears to be a simple straight-forward task, however, if not carefully conceived, the methodology employed can generate results that misinterpret numerical model forecast quality. Further comments on each aspect of the verification procedure are summarized below.

A. Observations

It is obvious that the most important part of the verification program is a network of good quality densely distributed observations. Experience with a station verification program, September 1978 to May 1982, showed that on average at least 20% of stations reporting rainfall had incorrect values; this average did not include stations with missing rainfall data. No adequate programming method exists to quality contral rainfall reports; the usual technique is to flag extremes in amounts; however, any reported value need not be correct and correct identification of true extremes produced by nature are beyond a programmer's capabilities.

Precipitation observation stations are non-uniformly distributed; there is a greater concentration over the more populated regions of the eastern U.S. and a greater number of reports for the longer 24 hour reporting period than for twelve or six or three hour periods. As model mesh lengths diminish, spatial distribution of observations become increasingly important; in essence, evaluation of fine-mesh model short range forecasts reduce to a station type program over portions of the verification network.

Radar reports are often used to fill in gaps in the observational network; this appears to be a reasonable approach, however, if only hourly radar summaries are used, what happens to the contribution to rainfall totals by convective cells with lifetimes on the order of one-half hour?

It is clear that the number of observations in a database is not the only important consideration; spatial distribution and quality of these reports are crucial since they dictate the limits to which the verification program can reasonably partition the verifying field.

B. Model Forecasts

Numerical models do not predict rainfall amounts by simulating the rainfall process; precipitation parameterization methods are used; parameters at each grid location determine total QPF. Depiction of the rainfall shield on charts or amounts at specific locations depend on interpolation methods; there are several; they illustrate both graphical and interpretation difficulties in the representation of model QPF.

In nature, heavy rainfall tends to be localized and characterized by very strong gradients; light rainfall is widely distributed with weak gradients. In graphical presentation of model QPF, contouring depends on rain or no rain values at adjacent gridpoints for the placement of the measureable rainfall line, and of one-half and whole inch contours. For very large QPF adjacent to small values interpolation expands heavy precipitation and weakens gradients. For the measureable precipitation line, its location depends on the choice of the negative constant used at adjacent no rain points; QPF greater than and less than the constant will expand and shrink rain areas respectively.

Specification of rainfall at a station location will also vary depending on the interpolation method used. Amounts will be greater or lesser as discussed above if model QPF at gridpoints are viewed as peak values; and quite different if model QPF is taken to represent an average amount over the forecast mesh.

All precipitation verification programs that require interpolation of the forecast field need to carefully consider what the model QPF represents. As model mesh length diminishes, interpola-difficulties will diminish, however, the spatial distribution of observations over the verification network will become increasingly important.

C. Objective Verification

1. The validity of numerical model precipitation verification program results depends on the proper treatment of forecast and observed fields; partitioning the verifying field inconsistently with the forecast field evaluates the model for precipitation scales it cannot predict. For example, consider the 24 hour observed precipitation charts in Figure V for two days in January 1982 (this example is from NMC Office Note 291); observed .50" and whole inch lines are contoured, Limited Area Fine-Mesh (LFM) grid points are at intersections of grid lines, and Spectral model points are indicated by crosses. Along A-A' in the top graph, the two lower Spectral points and nearby LFM points are in heavy precipitation while the intermediate LFM point is in a lesser precipitation area. If the observed field is partitioned in LFM mesh size and the Spectral model is assumed to have correctly forecast heavy precipitation at the Spectral points, then, at the intermediate LFM verification location, the interpolated Spectral amount is a large value and, therefore, evaluated as an incorrect prediction. The Spectral is correct for two out of the three verification points, i.e., LFM locations. Assuming that the LFM correctly predicted the observed distribution, the conclusion would be that the LFM was better than the Spectral; in reality the Spectral model is poorer because it did not predict a precipitation event it was not designed to predict.

In the bottom graph of Figure V, along B-B', each of the Spectral points are in lesser precipitation areas; if the Spectral forecast is the same as the observed at these locations, it is a perfect forecast for a verification system using the same grid spacing as the Spectral grid; however, if the verifying field was equal to the LFM mesh, the additional Spectral verification points would be interpolated to have rather small amounts and therefore incorrect. A similar argument can be made for the LFM if the verifying field is of a finer mesh length than the LFM mesh.

2. Statistics used to evaluate the quality of numerical model forecasts must be used correctly. Precipitation threat score is positively correlated with the occurrence of rainfall; accuracy of model QPF cannot be described by the TSP alone; the season, bias, and rainfall distribution are factors to consider.

3. The specification of various QP categories complicates the task of evaluation since events in the heavier rainfall categories are rather sparse. If a set of QP category scores are inadequate to evaluate model performance and the choice is to increase categories, this difficulty may well be due to an inconsistency in the treatment of forecast and observed fields and also the arbitrarily specified QP thresholds.

4. If the purpose of evaluation is to determine the usefulness of model QPF as perceived by the clients, it is also important to consider forecast verification on user grids whenever they differ with model forecast grids. Also, for numerical model intercomparisons it is only proper to evaluate on the coarser of the two grids.

5. Since model QPF is derived from parameterization methods and not from a simulation of the rainfall process, all of the observed precipitation is not predictable. In the large-scale process, model methods are quite adequate for mature storms; here, rainfall rate is equivalent to moisture converging into the system; in the developing and dissipating stages, model methods fail. The model bias, predicting rainfall for the correct reason, should be somewhat less than unity. Therefore, "tuning" model QPF by maximizing TSP by overforecasting, i.e., equating large TSP with quality, is a poor tactic; a bias near unity already represents an overforecast of what the model is capable of predicting; for heavy QPF, large biases are a serious problem.

QPF VERIFICATION: AN EXAMPLE

There are two precipitation parameterization methods used in the LFM. Large-scale precipitation is generated whenever relative humidity in model layers exceed a critical threshold value while subgrid-scale precipitation depends on moisture convergence and instability. Model gridpoint properties determine total precipitation; LFM mesh length is 190.5KM.

Results presented in this section are from an evaluation program using a verification network of North America LFM gridpoints covering the U.S. and portions of southern Canada adjacent to the lower Great Lakes; there are a total of 321 gridpoints. The foothills of the Rocky Mountains divides the network into west (WEST) and east (EAST) divisions; WEST and EAST have 106 and 215 gridpoints respectively.

The verifying field is an estimate of the average observed areal total at each LFM gridpoint. This makes both forecast and observed fields consistent since they represent the same scale of events; it is not necessary to interpolate forecast values, therefore, precipitation generated by model properties at gridpoints are confined to that location and cannot contribute to amounts at adjacent points. Further details are found in NMC Office Note 291.

Seasonal statistics from LFM QPF evaluation for 1983 are used in this discussion. There are five QP categories based on precipitation thresholds and two based on TSQP. They are:

CATEGORY	THRESHOLD	
1	.01"	categorical or rain/no rain
2	.25"	
3	.50"	
4	1.00"	
5	1.50"	
QP1	.01"	total rainfall
QP2	CRIT	

Category QP1 verifies all measureable forecast and observed precipitation; it is an overall measure of model performance in forecasting both large- and small-scale events. To determine model performance strictly with respect to heavier (CRIT, however defined) rainfall events, a TSQP for category QP2 is calculated; the critical value used in this section is .25" (see Figure IIIc).

A. East Division

Table I summarizes EAST TSP (X100) and B for each category for winter (WIN), spring (SPR), summer (SUM), and autumn (AUT). Average percentage observed areal distribution of rainfall is given as %R, average percentage distribution of amounts in excess of each QP threshold is given as %QP, and average observed precipitation amount is shown as AVG OBS.

In the rain/no rain (RNR) category:

1. WIN biases increase with time and are wet by 48 hours.
2. SUM biases are wet at 12 hours and decrease with time.
3. SPR and AUT have tendencies similar to WIN.

For QP category biases:

1. SUM biases are dry throughout the forecast cycle.
2. During the other seasons, forecasts are initially dry, biases increase with time, and in AUT and SPR decrease at 48 hours; overall, SPR biases are larger than AUT.

LFM QP1 and QP2 bias tendencies accurately describe the bias characteristics discussed above. In SUM, QP1 biases are dry throughout the forecast cycle; the LFM overforecasts convective areas (see RNR biases) and underforecasts QP amounts.

Observed areal distribution of rainfall is similar in WIN, SUM, and AUT while SPR has more than 20% greater coverage. During WIN more than half of the QP is concentrated in areas of GT .25" amounts whereas during SUM 58% of total rainfall is found in areas of less than .25".

The variation of threat scores shows that:

1. The LFM does poorest in SUM when convective activity do-

minates; it does best in WIN when precipitation is well-organized and large-scale.

2. Larger RNR TSP is found in SPR than in AUT because of greater %R overage; overall, however, QP1 and QP2 scores are quite similar.
3. Compared with transition seasons, WIN QP1 and QP2 scores are slightly better; even though %R in SPR is greater, forecasting is easier when precipitation regimes are primarily large-scale.

B. West Division

Table II summarizes 1983 season results for the WEST division. The format is the same as Table I.

In all seasons, LFM RNR category biases are wet at 12 hours and become much wetter with time. For QP threshold categories, the same tendency is found in WIN, SPR, and AUT except that SPR 12 hour bias is initially dry; SUM forecasts become drier in time.

QP1 and QP2 bias characteristics in WIN, SPR, and AUT are similar to the tendencies discussed above. In SUM, QP1 biases are large and nearly the same at all hours; in contrast with EAST forecasts, the LFM overforecasts both area and QP over the WEST during the hot season.

Threat scores vary with season and rainfall distribution; Note how slowly threat score decreases even with very large bias increases (see Figure II).

C. Summary

Evaluation of numerical model QPF is greatly simplified by using TSQP and BQP; the necessity of calculating and interpreting statistics from a large set of QP categories is eliminated.

CONCLUSION

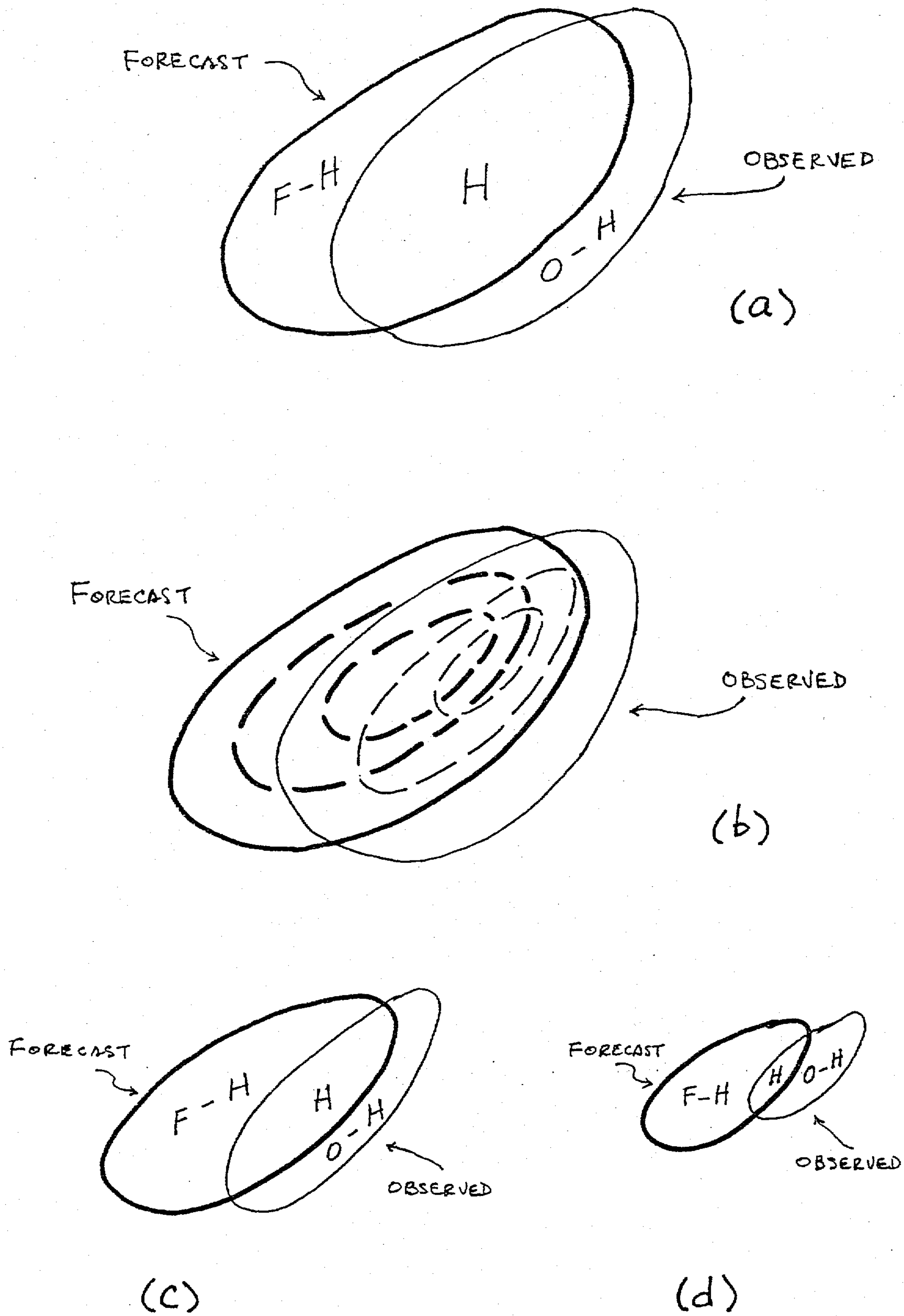
Precipitation verification is not simple. Constraints imposed by limitations in the observational database and objective statistics available mandate a careful description of the methodology used; otherwise, results and conclusions can be misleading and misinterpreted.

REFERENCES

Hirano, R., 1982: Systems Evaluation Branch Monthly Precipitation Verification. NMC Office Note 1982.

Hirano, R. and J. Johnson, 1984: NMC Operational Model Monthly Precipitation Verification, December 1981 - November 1983. NMC Office Note 291.

I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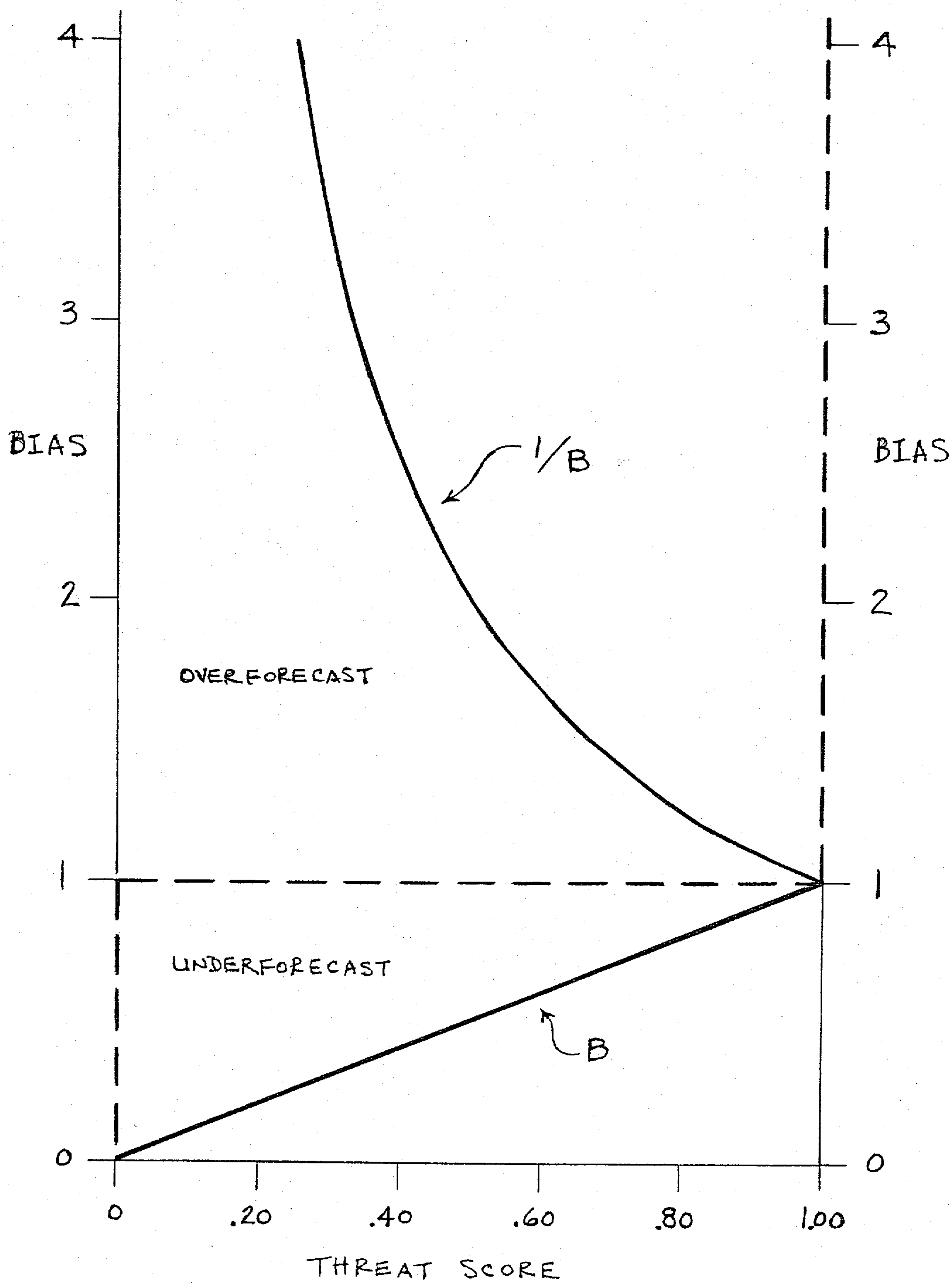
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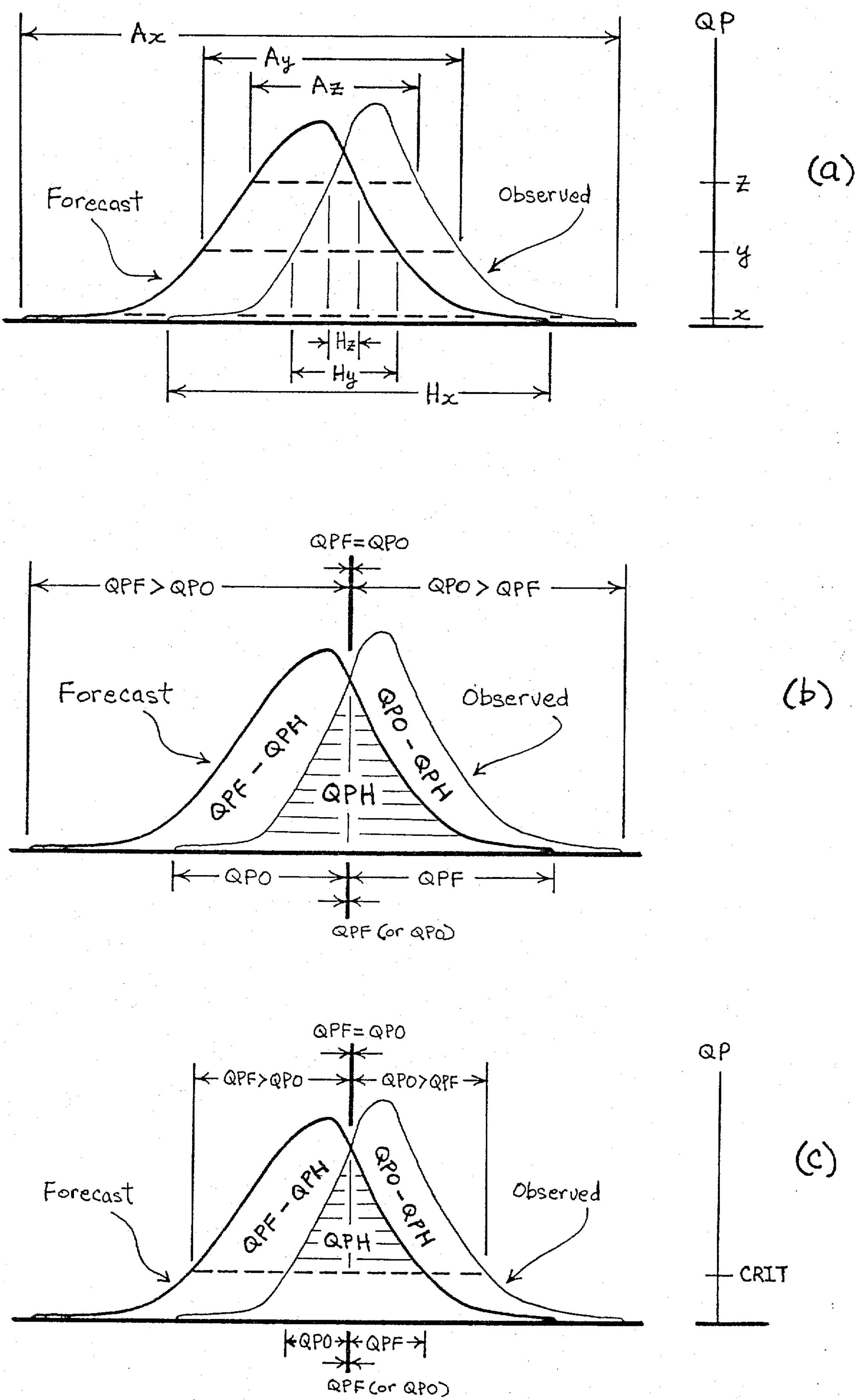
THREAT SCORE

III


Ax
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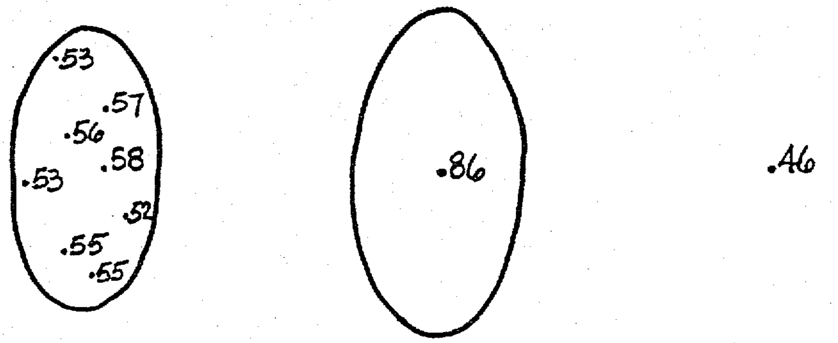
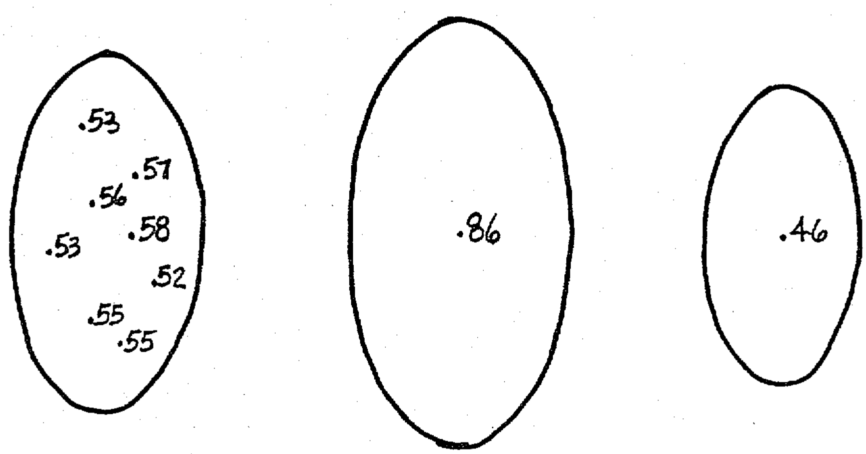
EXAMPLE 1: .50" CONTOUR ____________

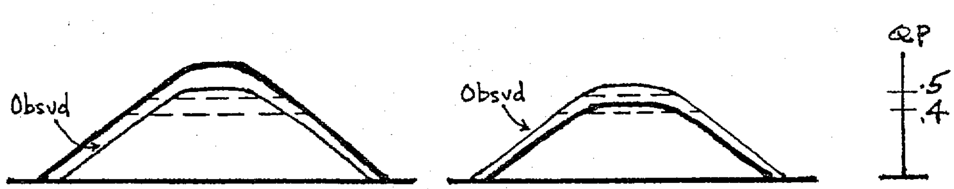


OBSVD FCST A FCST B

EXAMPLE 2: .40" CONTOUR ____________



OBSVD FCST A FCST B



QPF > QPO QPO > QPF

FCST A FCST B

24 HOUR OBSERVED PRECIPITATION
.5" (Thin), Whole Inch (Heavy)

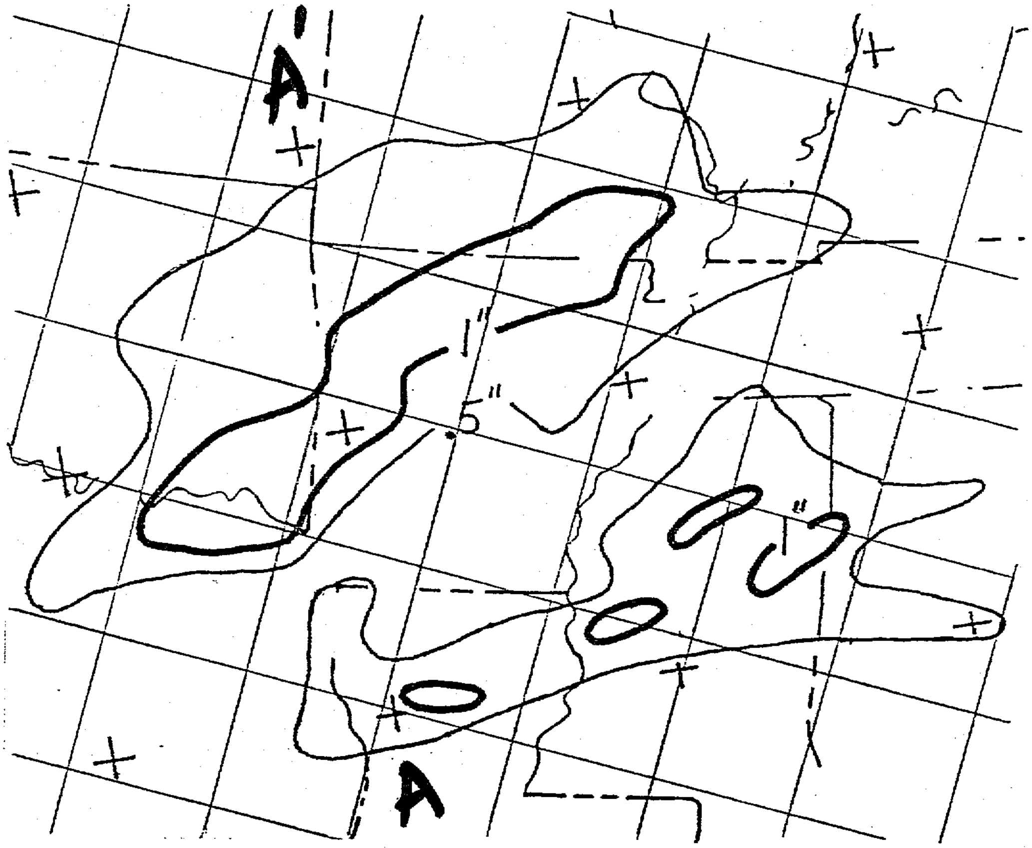


TABLE I: LFM 1983 EAST DIVISION QPF CATEGORIES

	%R /%QP	FORECASTS (TSP / B) . . . 12HR	24HR	36HR	48HR
WINTER					
.01"	20.5/100	52 / 0.95	48 / 1.26	43 / 1.37	38 / 1.45
.25"	4.8/ 51	43 / 0.91	36 / 1.37	30 / 1.45	26 / 1.46
.50"	2.5/ 31	34 / 0.94	28 / 1.46	24 / 1.51	18 / 1.44
1.00"	0.9/ 13	17 / 0.76	15 / 1.42	12 / 1.51	10 / 1.28
1.50"	0.4/ 6	7 / 0.51	9 / 1.19	5 / 1.47	5 / 0.94
SPRING					
.01"	24.7/100	55 / 1.17	51 / 1.37	46 / 1.45	41 / 1.49
.25"	7.4/ 49	36 / 0.93	36 / 1.33	29 / 1.42	22 / 1.29
.50"	3.8/ 28	28 / 0.84	28 / 1.44	19 / 1.54	14 / 1.29
1.00"	1.2/ 11	17 / 0.56	20 / 1.51	10 / 1.75	6 / 1.13
1.50"	0.4/ 5	7 / 0.29	11 / 1.73	4 / 1.88	3 / 1.05
SUMMER					
.01"	20.0/100	34 / 1.42	35 / 1.37	33 / 1.28	29 / 1.24
.25"	5.4/ 42	15 / 0.64	15 / 0.69	12 / 0.70	11 / 0.63
.50"	2.4/ 21	11 / 0.34	9 / 0.54	6 / 0.51	5 / 0.47
1.00"	0.6/ 5	4 / 0.15	3 / 0.47	1 / 0.31	1 / 0.40
1.50"	0.1/ 1	0 / 0.00	0 / 0.61	0 / 0.40	0 / 0.58
AUTUMN					
.01"	20.2/100	49 / 1.22	48 / 1.37	43 / 1.37	38 / 1.38
.25"	6.0/ 47	37 / 0.81	34 / 1.08	29 / 1.05	22 / 0.93
.50"	3.0/ 25	25 / 0.67	24 / 1.04	19 / 1.00	13 / 0.80
1.00"	0.8/ 7	14 / 0.53	12 / 1.00	5 / 0.88	2 / 0.70
1.50"	0.3/ 3	7 / 0.47	3 / 0.67	2 / 0.47	1 / 0.45

	AVG OBS	FORECASTS (TSQP / BQP) . . . 12HR	24HR	36HR	48HR
WINTER					
QP1	.22"	37 / 0.88	31 / 1.35	27 / 1.45	23 / 1.40
QP2		27 / 0.78	22 / 1.34	18 / 1.42	15 / 1.26
SPRING					
QP1	.26"	36 / 0.89	33 / 1.39	26 / 1.50	21 / 1.30
QP2		24 / 0.70	24 / 1.43	16 / 1.54	12 / 1.17
SUMMER					
QP1	.21"	20 / 0.78	19 / 0.85	16 / 0.79	14 / 0.77
QP2		10 / 0.35	9 / 0.56	6 / 0.51	5 / 0.51
AUTUMN					
QP1	.24"	34 / 0.88	32 / 1.14	27 / 1.11	22 / 1.00
QP2		23 / 0.65	22 / 1.00	17 / 0.95	12 / 0.79

TABLE II: LFM 1983 WEST DIVISION QPF CATEGORIES

	%R /%QP	FORECASTS (TSP / B) 12HR	24HR	36HR	48HR
WINTER					
.01"	23.0/100	51 / 1.36	45 / 1.82	40 / 1.99	36 / 2.13
.25"	4.6/ 38	30 / 1.25	26 / 2.17	20 / 2.24	17 / 2.65
.50"	2.0/ 18	27 / 1.02	20 / 1.87	16 / 2.08	14 / 2.56
1.00"	0.5/ 4	23 / 0.78	17 / 1.24	8 / 2.21	9 / 2.39
1.50"	0.1/ 1	19 / 1.17	8 / 1.39	6 / 1.91	5 / 2.43
SPRING					
.01"	22.1/100	47 / 1.51	43 / 1.86	40 / 1.98	37 / 2.02
.25"	3.1/ 26	21 / 0.85	21 / 1.79	17 / 1.85	16 / 2.24
.50"	1.0/ 10	17 / 0.67	15 / 1.56	14 / 1.70	12 / 2.63
1.00"	0.2/ 2	5 / 0.52	10 / 0.86	6 / 1.77	6 / 3.47
1.50"	* / 1	0 / 0.29	0 / 0.00	0 / 1.00	0 / 2.57
SUMMER					
.01"	16.4/100	30 / 1.70	32 / 1.82	30 / 2.05	27 / 2.07
.25"	1.4/ 18	5 / 1.42	8 / 1.42	4 / 1.33	7 / 1.19
.50"	0.4/ 6	3 / 1.49	4 / 1.16	3 / 0.64	5 / 0.60
1.00"	* / 1	0 / 1.25	0 / 1.25	0 / 0.00	0 / 0.44
1.50"	* / *	0 / 0.00	0 / 2.00	0 / 0.00	0 / 0.00
AUTUMN					
.01"	18.0/100	42 / 1.68	39 / 2.08	34 / 2.29	31 / 2.40
.25"	2.9/ 28	21 / 1.37	21 / 2.30	16 / 2.20	16 / 2.22
.50"	1.0/ 11	17 / 1.25	16 / 2.12	11 / 1.89	13 / 2.51
1.00"	0.1/ 2	14 / 1.19	10 / 1.46	6 / 2.31	5 / 4.68
1.50"	* / 1	7 / 0.67	7 / 0.78	4 / 2.00	5 / 3.33

	AVG OBS	FORECASTS (TSQP / BQP) 12HR	24HR	36HR	48HR
WINTER					
QP1	.17"	35 / 1.23	29 / 1.98	23 / 2.21	21 / 2.49
QP2		26 / 1.01	21 / 1.75	14 / 2.09	13 / 2.52
SPRING					
QP1	.13"	31 / 1.12	28 / 1.78	25 / 1.96	21 / 2.24
QP2		16 / 0.67	16 / 1.44	13 / 1.68	11 / 2.55
SUMMER					
QP1	.09"	15 / 1.62	18 / 1.69	17 / 1.77	15 / 1.76
QP2		3 / 1.37	5 / 1.28	2 / 0.81	5 / 0.75
AUTUMN					
QP1	.13"	28 / 1.54	25 / 2.24	21 / 2.38	19 / 2.57
QP2		19 / 1.32	16 / 2.06	12 / 2.11	12 / 2.77